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A LACTOMETER METHOD FOR DETERMINING THE SOLIDS IN MILK

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The increasing importance of the nonfat milk solids in the economy of the dairy industry has made it imperative to have at hand a rapid and economical method for determining milk solids which would be comparable in speed and accuracy to the Babcock test for fat. Hence, the Dairy Products Section of the Eastern Utilization Research Branch has made an intensive study of the problem directed toward the development of an economical and practical method for determining milk solids which would eliminate or minimize the difficulties previously encountered.

In this research a method of satisfactory accuracy was developed that takes advantage of the fact that butterfat is completely in the liquid state at 102° F. The method developed and tables for calculating total solids and solids-not-fat from Babcock determinations of fat and lactometric measurements are reported herein. The possible sources of error in lactometric work, and the historical development and validation of the Dairy Products Section method are to be presented in detail in another publication.

Lactometer Design

A glass lactometer was designed for the special requirements of this method. It requires a sample of about 10 oz. of milk. The dimensions were chosen to give the greatest sensitivity without having an excessively fragile instrument. It is possible to read this lactometer to 0.2 degree (2 in the fourth decimal place, expressed in specific gravity) and estimate to 0.1 degree. This lactometer, which is now commercially available, is illustrated in Figure 1.*

The Method in Practice

Lactometer Test.--Rapidly heat the milk sample (about 1/3 quart) to a temperature of approximately 102° F. by immersing the sample in warm water (about 115° F.). Gently shake the sample at intervals to prevent overheating. The flask should be loosely stoppered to reduce evaporation.

Transfer the sample with as little agitation as possible to a lactometer cylinder held in a water bath with the temperature thermostatically held at 102° F. The 102° F. lactometer should be preheated for not less than 3 minutes before using. This may be done by immersing the lactometer in a cylinder of water which is held in the same constant temperature bath as the milk sample. After preheating, remove the lactometer and wipe dry immediately prior to use.

* CATALOGUE NO. 22261. TAYLOR INSTRUMENT COMPANIES, ROCHESTER 1, NEW YORK. (MENTION OF THIS FIRM DOES NOT CONSTITUTE ENDORSEMENT OF ITS PRODUCTS BY THE U. S. DEPARTMENT OF AGRICULTURE OVER SIMILAR FIRMS OR PRODUCTS NOT MENTIONED.)

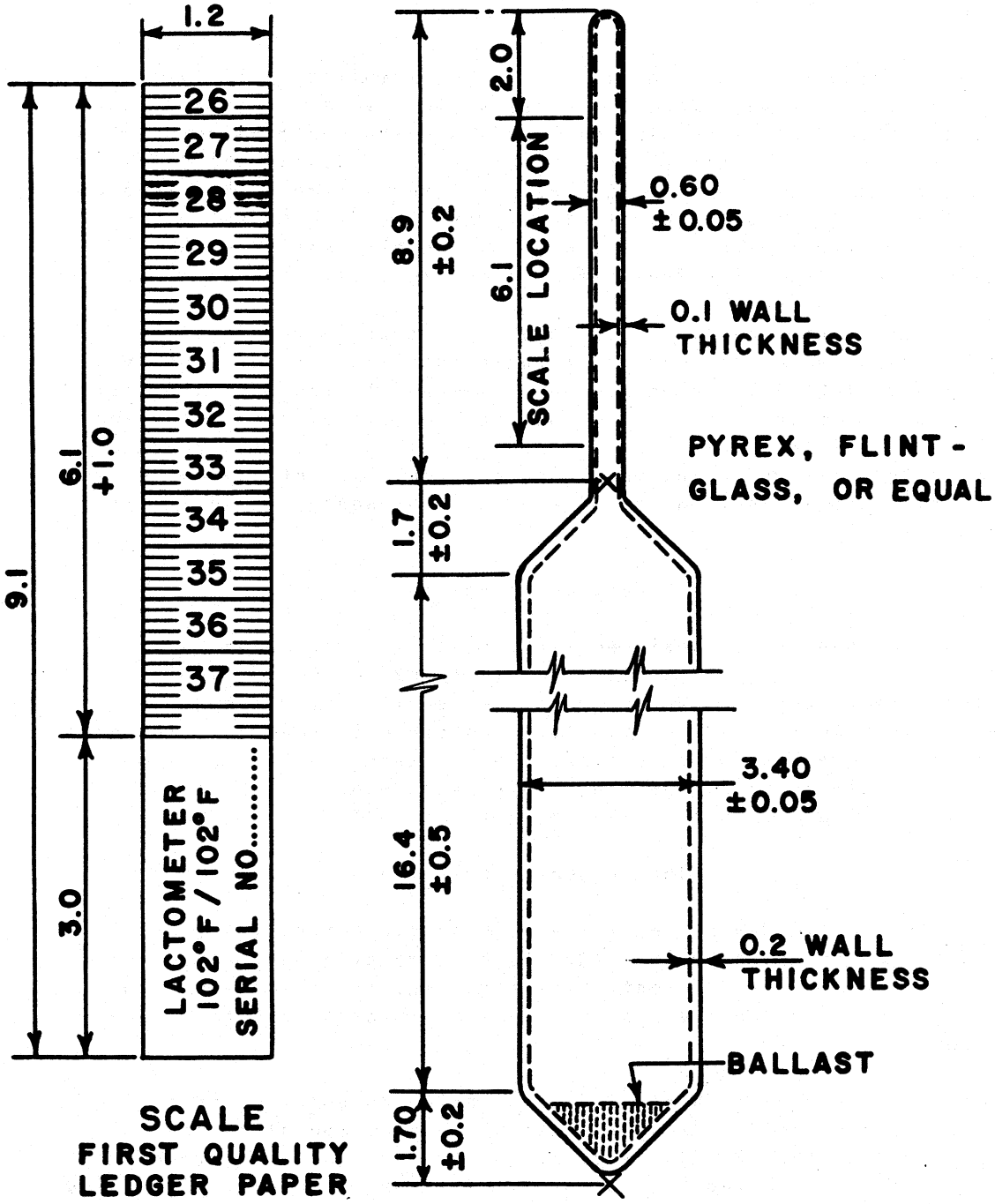

Figure 1

Lactometer

(Dimensions are in centimeters)

Slowly immerse the lactometer in the milk sample. The reading is taken at the top of the meniscus after coming to rest. It is important that the lactometer stem be clean and dry above the milk surface. Repeat readings can be made by withdrawing the lactometer just enough to permit wiping the stem clean with tissue or a soft cloth before slowly immersing it to the reading point.

Successive readings should agree by 0.1 degree if the temperature remains constant. The temperature of the milk should be checked with an accurate thermometer at the time of reading.

Butterfat Test.--The fat tests are conducted by the standard Babcock test or equivalent method. The surface of the milk should be adjusted to the graduation line in the 17.6 ml. pipette. The amount of fat should be read to the nearest 0.05 percent.

Calculation of Results

The accurate determination of total solids from lactometric measurements and fat determinations depends upon the finding by Whittier that the density of nonfat solids varies in a consistent manner with the fat content of the milk. The equation* derived by him and used in this work is:

$$\text{Total Solids (percent)} = 1.33\ F + \frac{273L}{L + 1000} - 0.40$$

F = Percentage of fat by Babcock method.
L = Lactometer reading in degrees.

The nonfat solids may be found by using 0.33 F instead of 1.33 F, or by subtraction of the fat percentage from the total solids percentage. Tables are appended which will simplify the calculations.

The total solids of skim milk samples may be calculated by dropping the constant -0.40 from the formula. The ordinary 60° F. lactometer may be used for measurements at 102° F. by adding 6.6 lactometer degrees to the reading before using the formula.

Accuracy of Results

In measurements on 99 samples from individual cows of six different breeds, the average deviation was found to be + 0.05 percent total solids. The standard error of estimate computed from these deviations (about the mean deviation) was ± 0.13 percent.

* THE ORIGINAL EQUATION CONTAINED THE CONSTANT -0.31. A RECALIBRATION OF THE LACTOMETER BY THE NATIONAL BUREAU OF STANDARDS HAS ALTERED THE VALUE OF THIS CONSTANT TO -0.40.

This can be interpreted as meaning that about two-thirds of the calculated values could be expected to fall within +0.05 ± 0.13 percent of the gravimetric total solids, or within from -0.08 to +0.18; and about 95 percent of the calculated values could be expected to fall within +0.05 ±0.26 percent of the gravimetric values, or within from -0.21 to +0.31.

In similar determinations of 101 mixed herd samples from about 25 herds of cows, the average deviation was -0.006 percent total solids, and the standard error of estimate was ±0.091 percent. Consequently, about 95 percent of the calculated values on mixed milk could be expected to fall within -0.006 ±0.182 percent of the gravimetric values, or within from -0.19 to +0.18.

Favorable reports which confirm the accuracy of this method have been received (private communications) from a dairy company in California, a dairy cooperative association in New York, the Dairy Technology Department of the University of Maryland, and the Dairy Husbandry Department of the University of Wisconsin.

General Suggestions. --A large number of determinations may be rapidly carried out by using several lactometer cylinders in a 102° F. constant temperature bath. The cylinders of milk may be held at this temperature for periods of upwards of 1 hour with only negligible change in the specific gravity, provided that the milk is gently stirred prior to the immersion of the lactometer. This long holding method is not suitable for use with milk in poor condition, which tends to become rancid or to "oil off".

When the milk samples are rather uniform in fat content, it is not necessary for practical work to wash and dry the lactometer between each measurement, because the error due to residual milk adhering to the lactometer in transfer from one sample to another is negligible. However, the instrument should be rapidly transferred and then only the stem need be wiped dry prior to each successive reading.

The following facts may be helpful to those workers who may desire to adjust the lactometer method to their own particular need for accuracy:

An error of 0.2 degree in a lactometer reading will result in a change in total solids of 0.05 percent.

An error of 0.1 percent in the determination of fat will result in a change of 0.13 percent in total solids.

A difference of 1° F. in temperature of milk will result in a change of 0.05 percent in total solids.

For those workers in the field who might want to use this method where no regulated water bath is at hand, it is suggested that the temperature be allowed to vary not more than two degrees away from 102° F. for the reading. For each degree above 102° F., the lactometer reading may be corrected by adding 0.2 lactometer degree, and for each degree below 102° F. the reading may be corrected by subtracting 0.2 lactometer degree from the reading.

Calculating the Total Solids

Tables I, II, and III will aid in using the formula when calculating percent of total solids. Table I gives values of 1.33 F for Babcock fat determinations (F) from 2.50 to 6.95. Table II gives values (listed as M) of $\frac{273L}{L + 1000} - 0.4$ for lactometer readings (L) from 25.5 to 34.9, which covers the range for whole milk. Table III gives values (listed as S) of $\frac{273L}{L + 1000}$ for lactometer readings (L) from 35.0 to 37.4, which covers the range for skim milk.

Thus, by the use of the tables, the calculation of the percentage of total solids in milk may be reduced to a simple addition.

CONVERSION TABLES FOR LACTOMETER DETERMINATION OF SOLIDS IN MILK

TABLE I

F	1.33F	F	1.33F	F	1.33F	F	1.33F	F	1.33F	F	1.33F
2.50	3.33	3.25	4.32	4.00	5.32	4.75	6.32	5.50	7.32	6.25	8.31
.55	3.39	.30	4.39	.05	5.39	.80	6.38	.55	7.38	.30	8.38
.60	3.46	.35	4.46	.10	5.45	.85	6.45	.60	7.45	.35	8.45
.65	3.52	.40	4.52	.15	5.52	.90	6.52	.65	7.51	.40	8.51
.70	3.59	.45	4.59	.20	5.59	.95	6.58	.70	7.58	.45	8.58
2.75	3.66	3.50	4.66	4.25	5.65	5.00	6.65	5.75	7.65	6.50	8.65
.80	3.72	.55	4.72	.30	5.72	.05	6.72	.80	7.71	.55	8.71
.85	3.79	.60	4.79	.35	5.79	.10	6.78	.85	7.78	.60	8.78
.90	3.86	.65	4.85	.40	5.85	.15	6.85	.90	7.85	.65	8.84
.95	3.92	.70	4.92	.45	5.92	.20	6.92	.95	7.91	.70	8.91
3.00	3.99	3.75	4.99	4.50	5.99	5.25	6.98	6.00	7.98	6.75	8.98
.05	4.06	.80	5.05	.55	6.05	.30	7.05	.05	8.05	.80	9.04
.10	4.12	.85	5.12	.60	6.12	.35	7.12	.10	8.11	.85	9.11
.15	4.19	.90	5.19	.65	6.18	.40	7.18	.15	8.18	.90	9.18
.20	4.26	.95	5.25	.70	6.25	.45	7.25	.20	8.25	.95	9.24

TABLE II

L	M	L	M	L	M	L	M	L	M
25.5	6.39	27.5	6.91	29.5	7.42	31.5	7.94	33.5	8.45
.6	6.41	.6	6.93	.6	7.45	.6	7.96	.6	8.48
.7	6.44	.7	6.96	.7	7.47	.7	7.99	.7	8.50
.8	6.47	.8	6.98	.8	7.50	.8	8.01	.8	8.53
.9	6.49	.9	7.01	.9	7.53	.9	8.04	.9	8.55
26.0	6.52	28.0	7.04	30.0	7.55	32.0	8.06	34.0	8.58
.1	6.54	.1	7.06	.1	7.58	.1	8.09	.1	8.60
.2	6.57	.2	7.09	.2	7.60	.2	8.12	.2	8.63
.3	6.60	.3	7.11	.3	7.63	.3	8.14	.3	8.65
.4	6.62	.4	7.14	.4	7.65	.4	8.17	.4	8.68
26.5	6.65	28.5	7.16	30.5	7.68	32.5	8.19	34.5	8.70
.6	6.67	.6	7.19	.6	7.71	.6	8.22	.6	8.73
.7	6.70	.7	7.22	.7	7.73	.7	8.24	.7	8.76
.8	6.72	.8	7.24	.8	7.76	.8	8.27	.8	8.78
.9	6.75	.9	7.27	.9	7.78	.9	8.30	.9	8.81
27.0	6.78	29.0	7.29	31.0	7.81	33.0	8.32		
.1	6.80	.1	7.32	.1	7.83	.1	8.35		
.2	6.83	.2	7.34	.2	7.86	.2	8.37		
.3	6.86	.3	7.37	.3	7.89	.3	8.40		
.4	6.88	.4	7.40	.4	7.91	.4	8.42		

TABLE III

L	S	L	S	L	S	L	S	L	S
35.0	9.23	35.5	9.36	36.0	9.49	36.5	9.61	37.0	9.74
35.1	9.26	.6	9.38	.1	9.51	.6	9.64	.1	9.77
35.2	9.28	.7	9.41	.2	9.54	.7	9.66	.2	9.79
35.3	9.31	.8	9.44	.3	9.56	.8	9.69	.3	9.82
35.4	9.33	.9	9.46	.4	9.59	.9	9.72	.4	9.84

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